The Amateur in You, Part 2

What have you been pondering?

Electrical components overview

In separate articles, we've discussed in-depth how a variety of electrical components work and how to use them in circuitry, including some calculations. This discussion provides you with a brief summary of the electrical components mentioned on amateur radio exams, and their general functions, without going into detail. It's intended for those who want an overview of these mysterious parts without a requiring degree in Electronics. Yet each component title name is a link to an in-depth article, if you'd like to learn that detail.

We'll focus mainly on the basic components, so necessarily we'll omit some very good and important ones that might appear on exams, because the scopes of their functions extend beyond what we'll consider to be the fundamental items. These missing devices include general ICs (integrated circuits), ADCs (analog-to-digital converters), grounds, lightning arresters, power supplies (except batteries), linear amplifiers, solar panels, and more.

Battery

The terms being used interchangeably, a ***battery*** or storage ***cell*** is a device that uses chemical reactions to store *electrochemical potential energy*. Each battery presents a set amount of electrical pressure, measured in **volts**, symbol **V**. If the types of chemicals in a battery are such that the chemical reactions are reversible, we call that a *rechargeable battery*. The following chemical equation illustrates this operation, such that when chemicals **A** and **B** react, they produce chemicals **C** and **D**, and release electrical energy:

A + B ↔ C + D + electrical energy

Then, if you attach the battery to a charger and insert the electrical energy, the process reverses, so that **C** and **D** "unreact" and form chemicals A and B again; hence, the double-direction arrow. It's kind of like accidentally creasing a piece of paper, then reversing the process by heating up the paper and smoothing out the crease.

If they are non-reversible, then it's a *single-use battery*, and you must not attempt to recharge it. The following chemical equation illustrates the non-rechargeable, one-way operation:

E + F → G + H + electrical energy

Once the energy has been expended, the **G** + **H** reaction will not accept more energy to change back into **E** + **F**; hence, the single-direction arrow.

Battery capacity is listed in **Ah** (ampere-hours, or amp-hours), indicating that (ideally) the battery can produce a certain amount of current (number of amperes) for each hour of operation. It's like tearing a piece of paper: while reversing that tear is *not completely impossible*, the paper's just not worth the cost. Each battery's data sheet will list the battery's nominal (set, within a tolerance) *voltage*, *capacity*, and *amperage* details.

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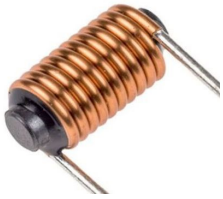
Resistor

A resistor is a passive electrical component that opposes current flow of all kinds, and whose opposition to current flow is not affected by signal frequency. Each fixed resistor possesses a specific amount of resistance (within a tolerance range), measured in **ohms**, symbol **Ω**. Its purpose is to drop voltage across it by reducing the flow of electrons through it. A *variable resistor*, also known as a *potentiometer*, also possesses a specific amount of resistance, but additionally has an adjustable contact that allows it to present a variable resistance within its preset range of resistance.

Inductor



An inductor is a passive electrical component that opposes the flow of AC (alternating current), and whose opposition to current flow increases as the current's frequency increases. Unlike a resistor, whose flow opposition occurs because of resistance, an inductor opposes current flow by *inductive reactance*, defined as

$$X_L = 2\pi fL$$

in which **f** is the frequency and **L** is the inductance in Henries, symbol **H**. An inductor can be a simple coil of wire, and it stores energy temporarily in a *magnetic field* created by the coil. Because an inductor acts like a short circuit at low frequencies and an open circuit at high frequencies, we can say that, by itself, it functions like a low-pass filter, allowing the signals of lower frequencies to pass through it while attenuating (reducing) those of higher frequencies. An inductor and capacitor can work together to form a tuned circuit by using *resonance*.

Capacitor

A capacitor is a passive electrical component that opposes the flow of AC (alternating current), and whose opposition to current flow decreases as the current's frequency increases. Unlike a resistor, whose flow opposition occurs because of resistance, a capacitor opposes current flow by *capacitive reactance*, defined as

$$X_C = 1/(2\pi fC)$$

in which **f** is the frequency and **C** is the capacitance in Farads, symbol **F**. A capacitor can be a simple pair of metal plates or conductors close to each other, and it stores energy temporarily in an *electric field*. Because a capacitor acts like an open circuit at low frequencies and a short circuit at high frequencies, we can say that, by itself, it functions like a high-pass filter, allowing the signals of higher frequencies to pass through it while attenuating (reducing) those of lower frequencies. A capacitor and inductor can work together to form a tuned circuit by using *resonance*.

Transformer

A transformer is an inductor that transfers electrical energy from one circuit to another. In the amateur radio world, the basic functions of transformers are to transform voltages and trans-

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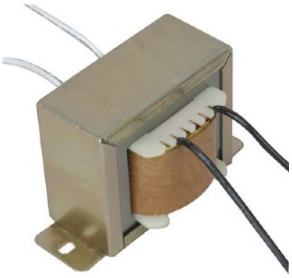

form impedances. They can made from a single wire (autotransformer), a pair of wires, or multiple wires, wrapped around a core made of iron, ferrite, or air. A transformer with a pair of wires can transform a lower voltage to a higher voltage (step-up transformer) or a higher voltage to a lower voltage (step-down transformer), because of the ratio between the number of wire turns on each side compared with that of the other.

We often refer to the two sides of a two-wire transformer as the primary side and the secondary side. Because the impedances of the two sides of such a transformer are directly proportional to the square of the turns ratio of the two sides, a transformer can be used to match impedances between circuits of different impedances, such as between a coaxial cable and an OFCD (off-center-fed dipole) antenna, to promote *maximum power transfer*.

Diode

A diode is an electrical component that allows current to flow through it in one direction. It's also called a *rectifier*; that is, it rectifies (makes positive) an AC (alternating current, or one that alternates directions) signal into a DC (direct current, or one that travels in one direction) signal. When the voltage across a diode is oriented such that current is allowed to flow through it, we say that the diode is *forward-biased*. The most common type of diode today is the silicon *semiconductor junction diode*, although there are many other useful ones, such as

Zener diode : provides a stable reference voltage in voltage regulator circuits, for example.

LED : a *light-emitting diode* emits visible or other kinds of light when it's forward-biased. It's a component that's quickly replacing energy-hungry incandescent bulbs around the world.

PV and photodiode : a photovoltaic cell (like you find in solar panels) and a photodiode are two examples of diodes that accept (not necessarily visible) light and transfer the *radiant energy* to the electrons, which result in current flow.

Germanium : material used for diode construction, which makes for a lower voltage drop and faster voltage change time, making it suitable for *demodulating* radio signals.

Others : include the Schottky, varactor / varicap, PIN, tunnel, and TVS, each of which provide valuable electronic functions.

Transistor

A transistor is a solid-state (not tube or gas-filled) device constructed from three or more *semiconductors* made of insulators that have had their chemistry altered to conduct electricity under certain conditions, and is arguably one of the greatest inventions of the 20th Century. The conditional conduction of the sandwiched semiconductors allow a transistor to amplify an input signal, such that the conduction is somewhat proportional to the input signal, making the output signal an enlarged (higher-power) replica of the input signal. A transistor can also work as an *electronically*

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controlled switch, to allow full conduction (called saturation) or no conduction, which forms the basic foundation for logic and computer circuitry.

Commonly used transistors include the BJT (bipolar-junction transistor), FET (field-effect transistor), and MOS (metal-oxide-semiconductor) types, but there are others. MOS is part of the FET family, and is better-called MOSFET because of the physical structure of a metal layer (typically Aluminum), an oxide layer (typically SiO_2), and a semiconductor layer (typically silicon) to perform transistor functions.

Vacuum tube

A vacuum tube is an electronic device that uses heated emissions of electrons passing between metallic objects to perform any of several functions, and enclosed in evacuated glass, metal, or ceramic. It was used as the first diode, because the electrons flowed only one direction, away from the heated cathode to the cooler anode. Depending on the type, a tube was once used as a *rectifier* (turns AC to DC), *amplifier*, *oscillator* (create sinusoidal waves), RF (radio frequency) *detector*, *mixer*, *demodulator*, and more. Plus, there are specialized vacuum tubes, such as the CRT (cathode-ray tube), magnetron, and X-rays.

Vacuum tubes were somewhat problematic, in that they required a lot of energy to perform their functions, and emitted a lot of heat as a result. Working with their high voltages could sometimes be a hazard. Because most had to maintain their vacuum in glass, the tubes were easily broken. And even when the glass remained intact, measures had to be manufactured in the tube to absorb any oxygen that leaked into the enclosure. As a result, their failure rate was relatively high, depending on the application.

Crystal oscillator

An *oscillator* is a device that produces a steady, periodic signal in the form of a sine wave or square wave. A crystal oscillator produces an oscillating signal by means of an physical piece of quartz or ceramic, which is very plentiful and can attain an oscillation of a very precise frequency. Typical crystal oscillators are able to generate oscillating frequencies to within a couple of parts per million, in spite of temperature changes, and provide the reference time base for computers and frequency synthesis in amateur radio. They're inexpensive, occupy little board space, possess automatic amplitude control, and require very little energy to maintain their oscillations.

Antenna

An antenna is a device that converts electrical signals into radio waves, collects radio waves, and converts received radio waves into electrical signals. In one form or another, nearly every antenna is a type of dipole, in that radio waves are emitted from one side of the dipole and received on the other side, then the two reverse operations a half-cycle later. The two sides are connected by *capacitance*, with air or space as the separating *dielectric*. An antenna that's

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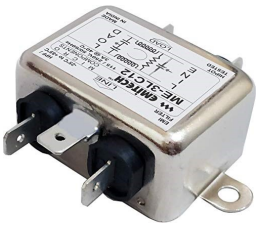
built using only one of these two halves still requires the missing counterpart, or *counterpoise*, for proper operation. In this case, an antenna will often make use of other things that can bring the signal back to the radio, such as the chassis of an HT (handheld transceiver) or the shield of the coax (coaxial cable), if one's attached.

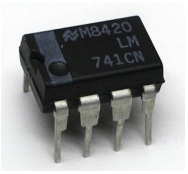
In the world of amateur radio, antennas have two basic arenas of function, *transmitting* and *receiving*. And because of *reciprocity*, each antenna's receive pattern is identical to its transmitting pattern, although experience doesn't always make that idea obvious. That *pattern* determines in what direction the antenna *gain* is pointed, and the directions of its relative signal *strengths* or *sensitivities*. And different antenna shapes, sizes (lengths), and especially its *height over ground*, affect that pattern.

Filter



A filter is a device that can be made from a single component, or more typically, a network of several things, usually resistors, inductors, and capacitors, arranged to perform their function together as a unit. Its purpose is to permit signals of specific frequencies to pass through it while rejecting signals of other frequencies. A filter can be very narrowly selective, passing only a small bandwidth of frequencies, such as with a *bandpass filter* or in a *tuning circuit*, or it can be made to pass signals of a very wide range of frequencies, such as with a *bandpass filter*. Some are designed to reject signals of specific types, such as in a *notch filter*.

Operational amplifier



An op amp (operational amplifier) is an IC (integrated circuit) made from a network of transistors and passive components to form a device that can not only be wired and configured to *amplify*, but to perform a number of other operations, such as that of an *oscillator*, a *filter*, and more. Because of its simplicity, low-cost, and versatility, the op amp can be found in most of today's electronics.

Switch

Is a switch an electrical component? Why not. The primary purpose of most electrical switches is to complete or break the path of electrical current. While a switch can be used to open or close a circuit at any spot, it's a vital part of most electrical pathways that provide electrical power to a device. The variety of switch types is huge, and include toggle, momentary, digital, relay, rotary, pushbutton, rocker, tactile, knife, dimmer, DIP, selector, capacitive, and combination, to name a few. Switches can be activated manually, automatically, electronically, or other by other means, such as makeshift (contrived, like simply plugging in the power cord). Some are "make-before-break" types.

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